Summary Report of the 4th stage (2013–2017) LTP Project

2019

Joint Research Project for Long–range Transboundary Air Pollutants in Northeast Asia

1. Introduction

In order to establish common understanding of mechanism of transboundary movement of pollutants, the three countries of Korea, China, and Japan have held LTP Expert Meetings since1996. The objectives of the LTP project are to study the state of air quality, the influence of neighboring countries, and the policy making of each country to improve the air quality. The LTP project has been executed in the four stages as below:

1st stage (2000–2004) – Built the foundation for collaborative research of measurements and modeling
2nd stage (2005–2007) – Drew the S–R (Source–Receptor) relationship for sulfur compounds by using the emission data agreed upon by the three counties
3rd stage (2008–2012) – Updated the emission inventory and extend the research area to nitrogen compounds
4th stage (2013–2017) – Focused on the S–R relationship of $PM_{2.5}$ concentrations over Korea, China, and Japan

This report summarizes the results of the 4th research stage (2013–2017) of the joint research project for Long–range Transboundary Air Pollutants in Northeast Asia (LTP).

2. Integration and Analysis of the LTP Measurements

The monitoring sites in the three countries: China, Korea and Japan, were selected under an agreement of the Joint Operating Committee for LTP project to capture transboundary movement of air pollutants in Northeast Asia.

2.1 LTP Monitoring sites

China, Korea, and Japan selected Dalian, Yantai and Xiamen; Baengnyeong, Ganghwa, Taean and Gosan; and Rishiri and Oki, as the monitoring sites, respectively (Fig.2.1).

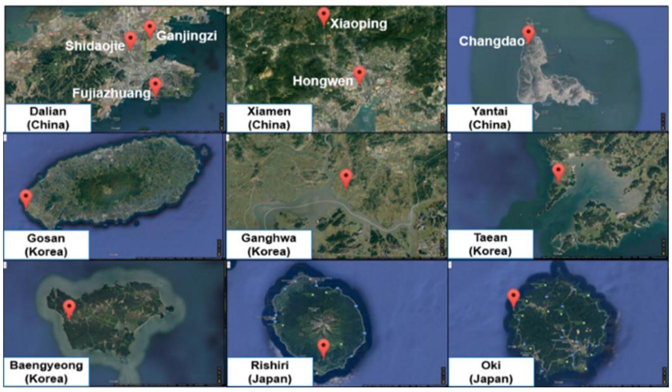

Fig. 2.1 Locations of monitoring sites in three countries for LTP project (Google map).

Table 2.1 Profiles of monitoring sites in three countries.

Country	Site name		Site type	Data reporting year	Latitude	Longitude
China	Dalian	Shidaojie	Urban	2002−2017	38°57'N	121°33'E
		Ganjingzi	Urban	2002−2017	38°58'N	121°36'E
		Fujiazhuang	Urban	2002−2017	38°51'N	121°37'E
	Xiamen	Xiaoping	Rural	2002−2014	24°51'N	118°02'E
		Hongwen	Urban	2002−2014	24°41'N	118°08'E
	Yantai	Changdao	Remote	2015–2017	38°11'N	120°44'E
Korea	Gosan		Remote	2000−2017	33°17'N	126°09'E
	Ganghwa		Rural	2000−2017	37°53' N	126°27'E
	Taean		Rural	2000−2017	36°44' N	126°08'E
	Baengnyeong		Remote	2013−2017	37°57' N	124°37'E
Japan	Rishiri		Remote	2000−2017	45°07'N	141°14'E
	Oki		Remote	2000−2017	36°17'N	133°11'E

Locations and information regarding the monitoring sites in the three countries are shown in Table 2.1.

The monitoring sites in China are in three cities. Of these, Dalian and Yantai are in the northern part of China, and Xiamen is in the southern part. Dalian City is in the coastal area of Liaoning Province, and it hosts three monitoring sites (Shidaojie, Ganjingzi, and Fujiazhuang). Yantai City is in the coastal area of Shandong Province, and it hosts one monitoring site (Changdao). Xiamen City is in the coastal area of Fujian Province, and it hosts two monitoring sites (Xiaoping and Hongwen).

Four monitoring sites in Korea are located on the west coast (Baengnyeong Island, Ganghwa Island, and Taean) and in Gosan on Jeju Island. Baengnyeong monitoring site is in the northern part of the west coast of Korea. Ganghwa monitoring site is in the western part of Seoul, and at this site, air pollutants flowing in from the metropolitan area can be evaluated. The Taean monitoring site can monitor air pollutants entering the central–west region of Korea. Gosan monitoring site is a representative background site in northern Asia, and it is located on the western coast of Jeju Island.

The monitoring sites in Japan are on two islands. Rishiri monitoring site is on an island northwest of Hokkaido in northern Japan. Oki monitoring site in the southwestern part of Japan is located on an island between Japan and the Korean peninsula.

2.2 LTP Monitoring Results

2.2.1 Long–term Monitoring Results

In 2017, the annual average concentrations of SO_2 were 4.8 ppb, 2.6 ppb, and 0.2 ppb in the monitoring sites of China, Korea, and Japan, respectively. China has shown a sharp decline since 2007, and Korea has shown a slight decline since 2011 and a slight increase since 2015.

Japan showed relatively low concentrations with no clear declining trend, and the concentration remained relatively constant (Fig. 2.2).

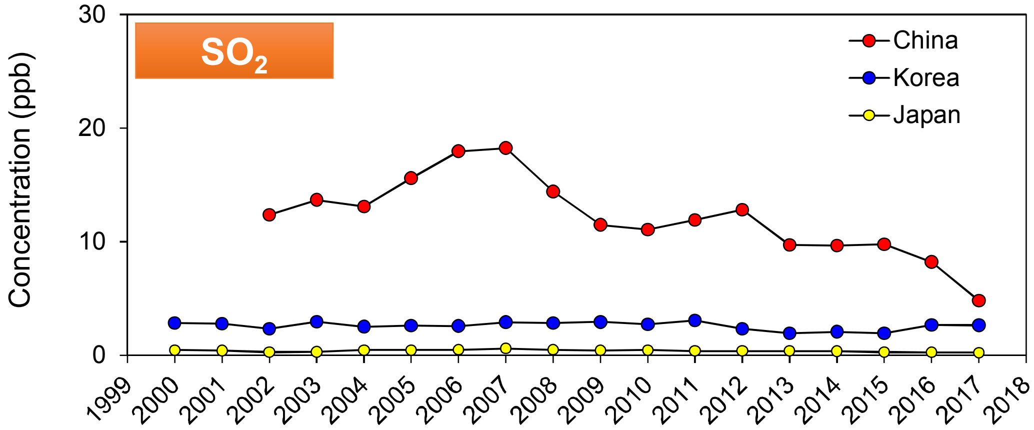

Fig. 2.2 Yearly mean concentrations of SO_2 in long–term monitoring period in China, Korea and Japan. Concentrations at the individual sampling sites were averaged.

The annual average concentrations of NO_2 in 2017 were 9.8 ppb, 7.2 ppb, and 0.8 ppb in monitoring sites in China, Korea, and Japan, respectively. It should be noted that NO_2 at remote sites may contain some parts of PAN and HNO_3. The average concentration in China increased steadily until 2011, and then declined notably, whereas those in Korea and Japan have remained relatively stable with minor annual variations. However, the average concentration in Korea slightly increased recently (Fig. 2.3).

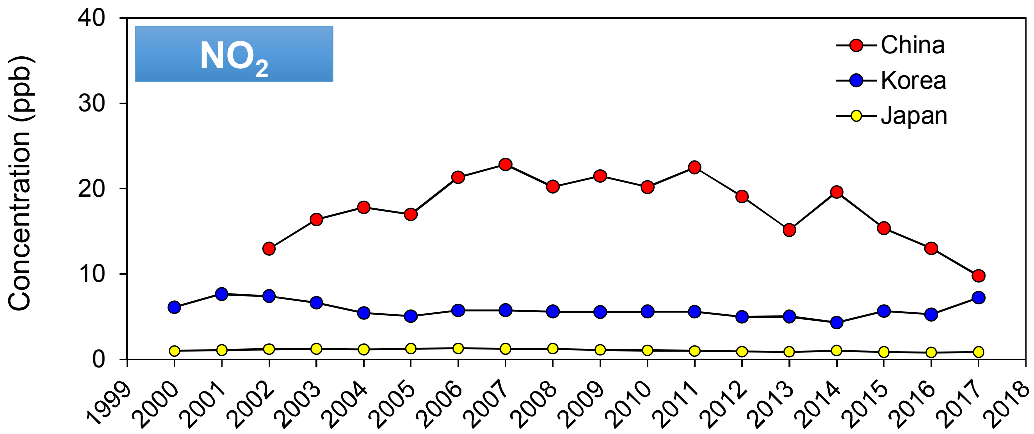

Fig. 2.3 Yearly mean concentrations of NO_2 in long–term monitoring period in China, Korea and Japan. Concentrations at the individual sampling sites were averaged.

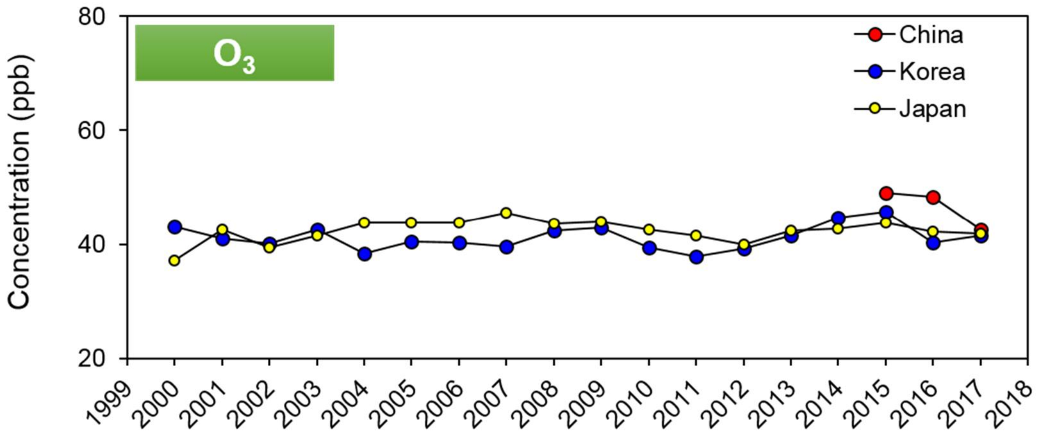

Fig. 2.4 Yearly mean concentrations of O_3 in long–term monitoring period in China, Korea and Japan. Concentrations at the individual sampling sites were averaged.

The annual average concentrations of O_3 in China (42.6 ppb), Korea (41.6 ppb) and Japan (41.9 ppb) were similar in 2017. China shows a decline trend since its monitoring O_3. The annual average concentrations of O_3 in Japan were not significantly different by year. In the case of Korea, there has been an increasing trend since 2011, but in overall, the concentrations have remained relatively constant (Fig. 2.4).

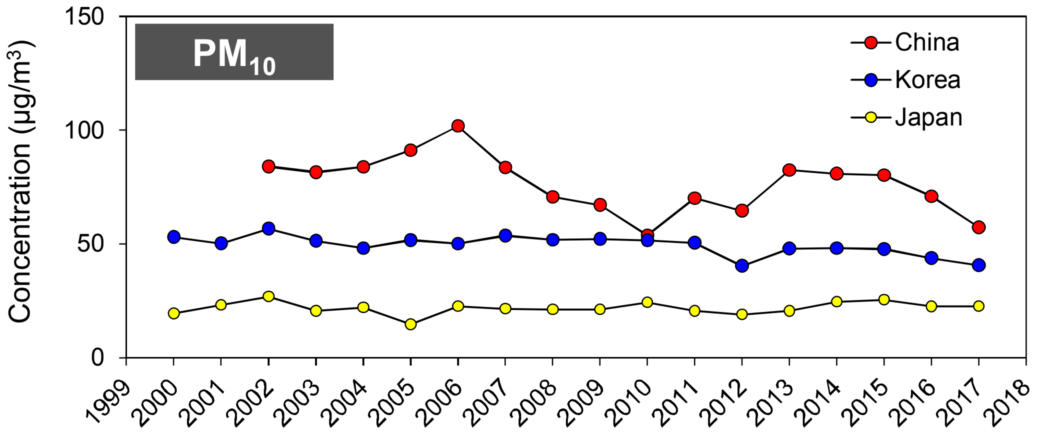

Fig. 2.5 Yearly mean concentrations of PM_{10} in long–term monitoring period in China, Korea and Japan. Concentrations at the individual sampling sites were averaged.

The annual average concentrations of PM_{10} were 57.3 $\mu g/m^3$, 40.6 $\mu g/m^3$, and 22.7 $\mu g/m^3$ in the monitoring sites of China, Korea, and Japan, respectively (Fig. 2.5). Considering that China and Korea have annual environmental standards of 70 $\mu g/m^3$ (2nd level of the National Standard) and 50 $\mu g/m^3$, respectively, the recent concentration in China did not exceed the standard in China. China showed a declining trend in PM_{10} concentrations since 2006, which was temporarily reversed from 2010 to 2013 and again has shown a decreasing trend since 2013. Korea and Japan have shown declining trends, and their concentrations have been steadily decreased.

The annual average concentrations of $PM_{2.5}$ were 34.3 $\mu g/m^3$, 20.1 $\mu g/m^3$, and 9.5 $\mu g/m^3$ in the monitoring sites of China, Korea, and Japan, respectively. China and Korea have shown a declining trend since 2014 and 2013, respectively (Fig. 2.6).

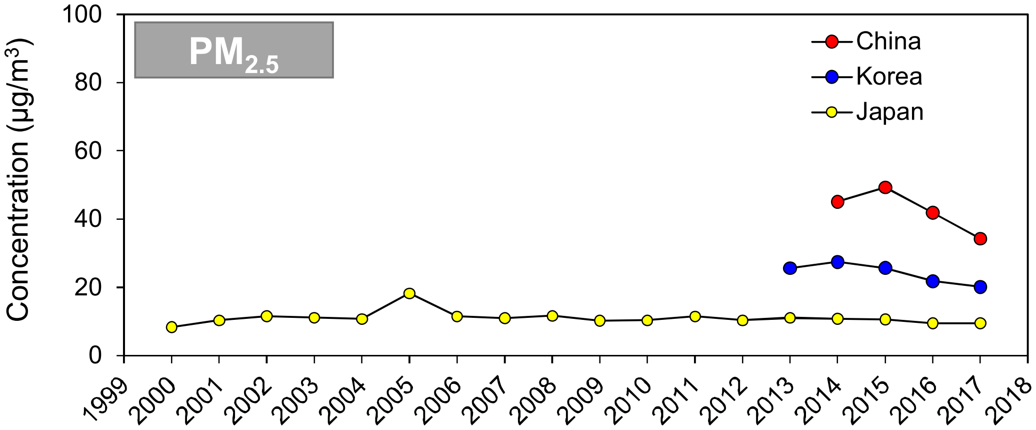

Fig. 2.6 Yearly mean concentrations of $PM_{2.5}$ in long–term monitoring period in China, Korea and Japan. Concentrations at the individual sampling sites were averaged.

2.2.2 Intensive Monitoring Results

According to the daily variations in $PM_{2.5}$ mass and water–soluble ion concentrations at five sites in China and Korea during the 2015 to 2017 intensive monitoring periods, it is clear that SO_4^{2-}, NO_3^-, and NH_4^+, emitted mainly from anthropogenic emission sources such as mobile, industrial, and residential sources were the major chemical components of $PM_{2.5}$ over East Asia. Moreover, notably, the fractional ratios of eight water–soluble ion components to the total $PM_{2.5}$ mass gradually increased from China to Korea.

2.2.3 National $PM_{2.5}$ trend of each country

Tremendous efforts have been made by the three countries to reduce air pollutants emissions in recent years. The monitoring data from 338 cities in China shows that $PM_{2.5}$ concentrations decreased significantly in recent years by around 22% nationwide from 2015 to 2018. Japan has shown a slightly decreasing trend in its $PM_{2.5}$ concentration from 13.1 µg/m^3 in 2015 to 11.6 µg/m^3 in 2017. Korea has also decreased its $PM_{2.5}$ concentration from 26 µg/m^3 in 2015 to 23 µg/m^3 in 2018, and in an effort to improve air quality, the Korean government strengthened the national air quality standard for $PM_{2.5}$ from 50 µg/m^3 to 35 µg/m^3 in 2018. Each country's $PM_{2.5}$ trend is depicted in Fig. 2.7.

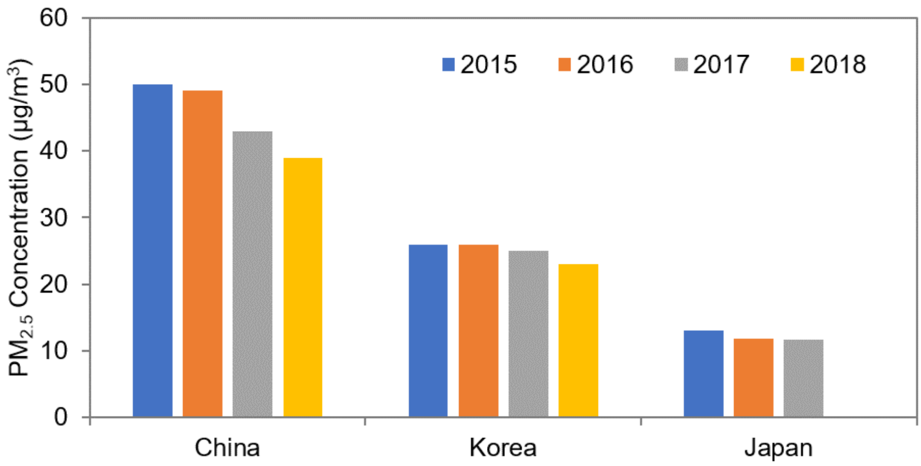

Fig. 2.7 Annual $PM_{2.5}$ concentration trend of the three countries (Japan's value for the year 2018 was not available at the moment when this report was created.)

3. Integration and Analysis of the Modeling Results

As a part of the LTP project, air quality modeling studies were conducted to identify the Source–Receptor (S–R) relationships among three countries, and results from three countries for the base year, 2017, are summarized in this chapter.

3.1 Model and Modeling Domain

During the 4th stage of LTP, the S–R relationships for $PM_{2.5}$ were estimated over China, Korea and Japan, for the base year of 2017. For meteorology and air quality, models, WRF–CAMx (by China), and WRF–CMAQ (by Japan and Korea) were employed, and the used emission data is the merged emission inventory from those provided by three countries: China (provided by CRAES), Korea (provided by NIER) and Japan (provided by ACAP).

The LTP domain covers Northeast Asia with the longitude approximately from 70°E to 150°E and the latitude 20°N to 55°N, thus it includes most of the part of China, Korea, and Japan (both South and North), some parts of Mongolia and Russia, and some Southeast Asian countries. The Lambert–Conformal Conic map projection was employed, with the center point set at 37°N, 123°E. The twelve receptor cities for the analysis of S–R relationship were agreed as shown in Table 3.1.

Table 3.1 Twelve receptor cities for S–R relationship analysis and their locations.

Country	Receptor City	Main Point (lat, lon)	
		Latitude	Longitude
China (CHI)	Beijing (BEI)	39°58′N	116°24’E
	Tianjin (TIA)	39°04’N	117°18’E
	Shanghai (SHA)	31°13’N	121°24’E
	Qingdao (QIN)	36°06’N	120°24’E
	Shenyang (SHE)	41°45’N	123°24’E
	Dalian (DAL)	39°03’N	121°44’E
Korea (KOR)	Seoul (SEO)	37°32’N	126°55’E
	Daejeon (DAE)	36°21’N	127°22’E
	Busan (BUS)	35°10’N	129°04’E
Japan (JPN)	Tokyo (TOK)	35°41’N	139°43’E
	Osaka (OSA)	34°36’N	135°29’E
	Fukuoka (FUK)	33°35’N	130°24’E

3.2 Emission Data

The LTP emission inventory was completed for the year, 2017 (LTP–2017 emission). The emission data from three countries were provided by CRAES (over China) of the year 2017, NIER (over Korea) and ACAP (over Japan) of the year 2015 and then merged over the LTP modeling domain. A common template was used to unify emission data of each country with the same emission source category system, and was mosaicked with each country's emission to generate hourly emissions with a horizontal resolution of 36 km over the domain. As an emission of gases biogenic emission from Nature, MEGAN2 was employed (Guenther et al., 2006).

3.3 Source–Receptor (S–R) Relationship for $PM_{2.5}$

The annual mean S–R relationships for $PM_{2.5}$ in 2017 were calculated. The 2017 results of S–R relationship simulations show that the local emissions dominate the $PM_{2.5}$ concentrations in each major city, including polluted days. The self–contributions in China, Korea and Japan are 91.0%, 51.2%, and 55.4%, respectively. The influences of $PM_{2.5}$ are mutual among China, Korea and Japan. China's contributions to major cities in Korea are 32.1%, and to major cities in Japan are 24.6%. Korea's contributions to major cities in Japan are 8.2%, and to major cities in China are 1.9%. Japan's contributions to major cities in China are 0.8%, and to major cities in Korea are 1.5%.

3.4 Uncertainties

The $PM_{2.5}$ simulated by CAMx/CMAQ models, in overall, agreed with some underestimations against observations for all of the twelve receptor cities. Also, several limitations were found in the modeling process as follows:

1) Uncertainties in the modeling methodologies of Source−Receptor Relationship and meteorological fields
2) Uncertainties in Emission inventory and coarse grid resolution
3) Uncertainties in chemical, aerosol, and meteorological mechanisms

However, those simulations are still considered reasonable for analyzing and diagnosing the conditions of air quality.

4. Summary and Suggestions

In order to establish common understanding of the mechanism of transboundary movement of air pollutants, experts from China, Korea and Japan shared data and information and discussed their monitoring and modeling results. To date each country has accomplished the measurement, model improvement, and model simulation through the LTP Project. The results shared at the 22nd Exert Meeting are reported, while the expert shared the view that methodologies need to be further improved.

The following results for monitoring and modeling are highlighted.

1. The first Summary Report for TEMM jointly produced by the three countries on long–range transboundary air pollutants in Northeast Asia. In order to investigate the characteristics of air pollution, three countries have carried model simulations based on the same recent emission inventory generated through the LTP Meeting.
2. The annual average concentrations of SO_2, NO_2, $PM_{2.5}$ and PM_{10} have shown a decreasing trend in recent years in the LTP monitoring sites in China, Japan, and Korea.
3. It was agreed that, even though there are some uncertainties in modeling and limitations in monitoring, the three countries have successfully diagnosed the decreasing trend of air pollution in Northeast Asia.
4. The modeling results of the three countries are quite similar with some exceptions and are in line with the monitoring data and basic natural settings of Northeast Asia.
5. The dominant contribution to the concentrations in each country is domestic emission in general and highlights the importance of emission reductions for improving domestic and regional air quality.
6. Further research on species–targeted monitoring and emission reduction will effectively contribute to improve air quality through continuous cooperation among the three countries.

5. APPENDIX

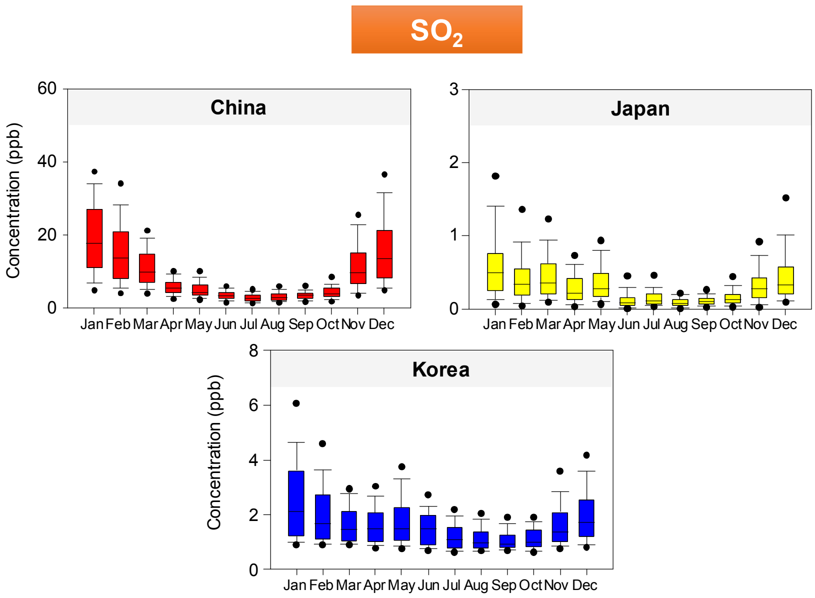

Fig. A.1 Variation of the monthly mean concentrations during 5 years (2013~2017) of SO_2 in monitoring sites in China, Korea and Japan.

The three countries showed typical seasonal variations in the concentration of SO_2 (high in winter and low in summer). This is probably because an increase in fossil fuel consumption during winter for heating, oxidization of sulfur in the fuel during the combustion process and unfavorable meteorological conditions generally lead to an increase in SO_2 concentrations (Fig. A.1).

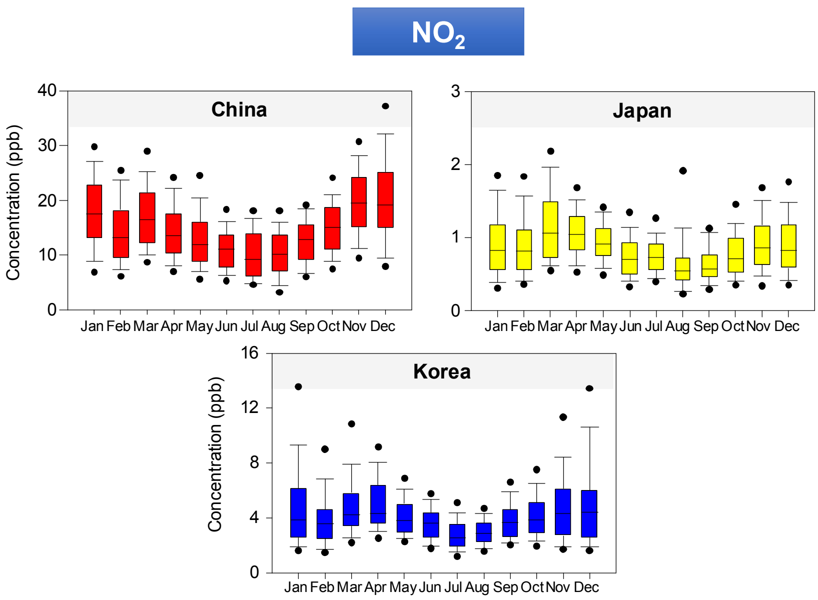

Fig. A.2 Variation of the monthly mean concentrations during 5 years (2013~2017) of NO_2 in monitoring sites in China, Korea and Japan.

NO_2 also showed the typical seasonal variation (high in winter and low in summer) owing to primary emissions (Fig. A.2). However, the seasonal changes were not as pronounced as in SO_2. Compared to SO_2, NO_2 was emitted to be relatively constant during the year from various sources as well as heating fuel.

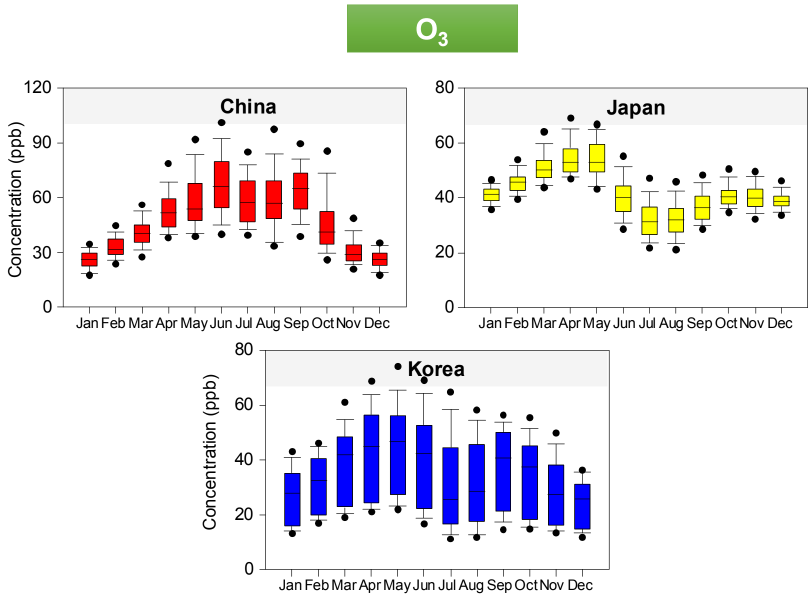

Fig. A.3 Variation of the monthly mean concentrations during 3 years (2015~2017) of O_3 in monitoring sites in China, Korea and Japan.

In China, the concentrations of O_3 were the highest in summer and lowest in winter. In Korea and Japan, the O_3concentrations were highest and lowest in spring and summer, respectively. Then, they tended to increase in autumn and decrease in winter (Fig. A.3). During summer, clean air mass is transported by south wind, leading to a decrease in O_3 concentrations. The effects of solar radiation and temperature might be stronger than those of precursor concentration.

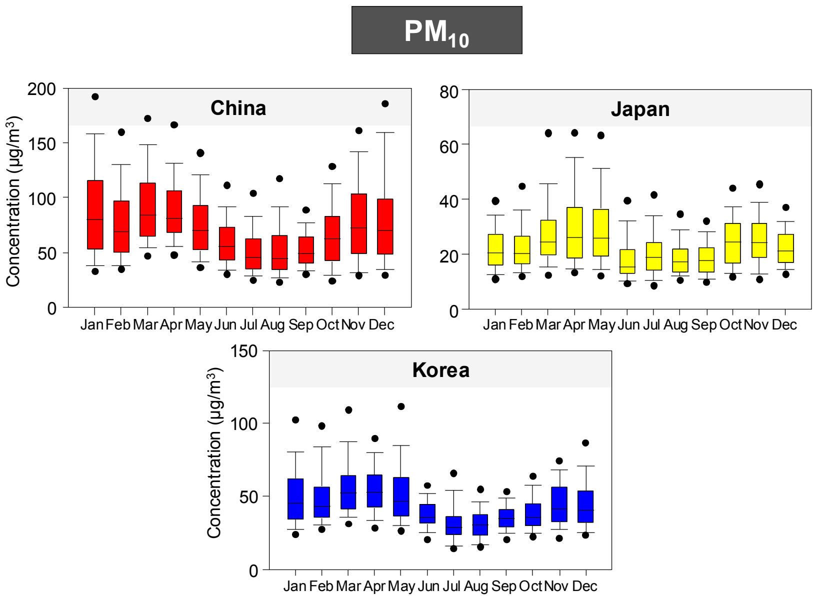

Fig. A.4 Variation of the monthly mean concentrations during 5 years (2013~2017) of PM_{10} in monitoring sites in China, Korea and Japan.

Monthly average concentrations of PM_{10} were high in winter and spring, and low in summer. This variation in concentration may have occurred owing to the increased amount of fuel consumption and long–range transport in winter, precipitation in summer, and occurrence of Asian dust in spring (Fig. A.4). In addition, elevated concentrations were observed, regardless of season, which may likely have been influenced by a variety of local sources, including biomass burning.

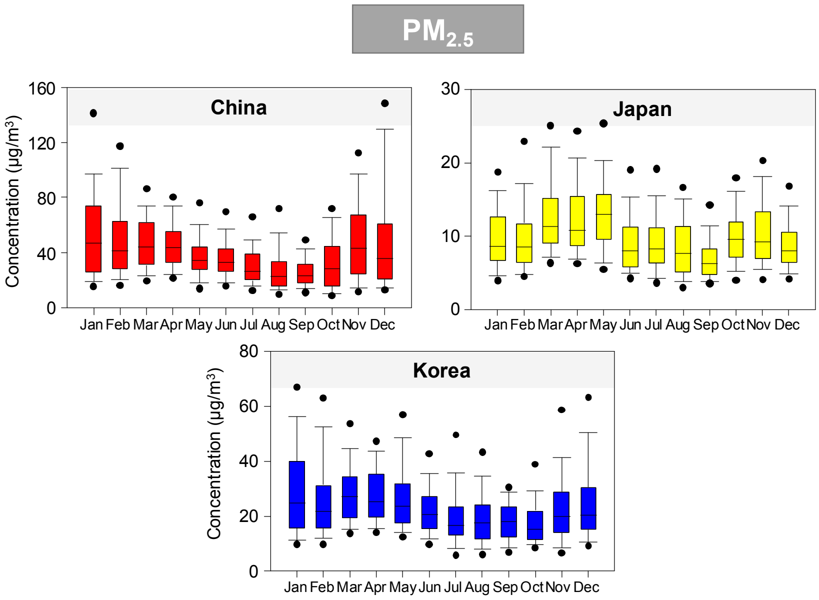

Fig. A.5 Variation of the monthly mean concentrations during 3 years (2015~2017) of $PM_{2.5}$ in monitoring sites in China, Korea and Japan.

Monthly average concentrations of $PM_{2.5}$ were high in winter and spring, and low in summer (Fig. A.5), similar to PM_{10}. However, unlike PM_{10}, the $PM_{2.5}$ concentration was higher in summer than in autumn, which was due to the secondary formation effect by the photochemical reactions in the summer. In addition, seasonal variations were similar to those of PM_{10} until 2000, but high concentration episodes occurred in various seasons after 2000. It seems to be caused by secondary formation and long–range atmospheric transport effect.

Acronyms

LTP Long-range Transboundary Air Pollutants in Northeast Asia

PAN Preoxyacetyl nitrate

ACAP Asia Center for Air Pollution Research

CRAES Chinese Research Academy of Environmental Sciences

NIER National Institute of Environmental Research

WRF Weather Research and Forecasting Model

CAMx Comprehensive Air Quality Model with Extensions

CMAQ Community Multiscale Air Quality Modeling System

MEGAN Model of Emissions of Gases and Aerosols from Nature

S-R Source-Receptor

TEMM Tripartite Environment Minister's Meeting